Evaporative Emission Inventory

Small Offroad Equipment

November 2002

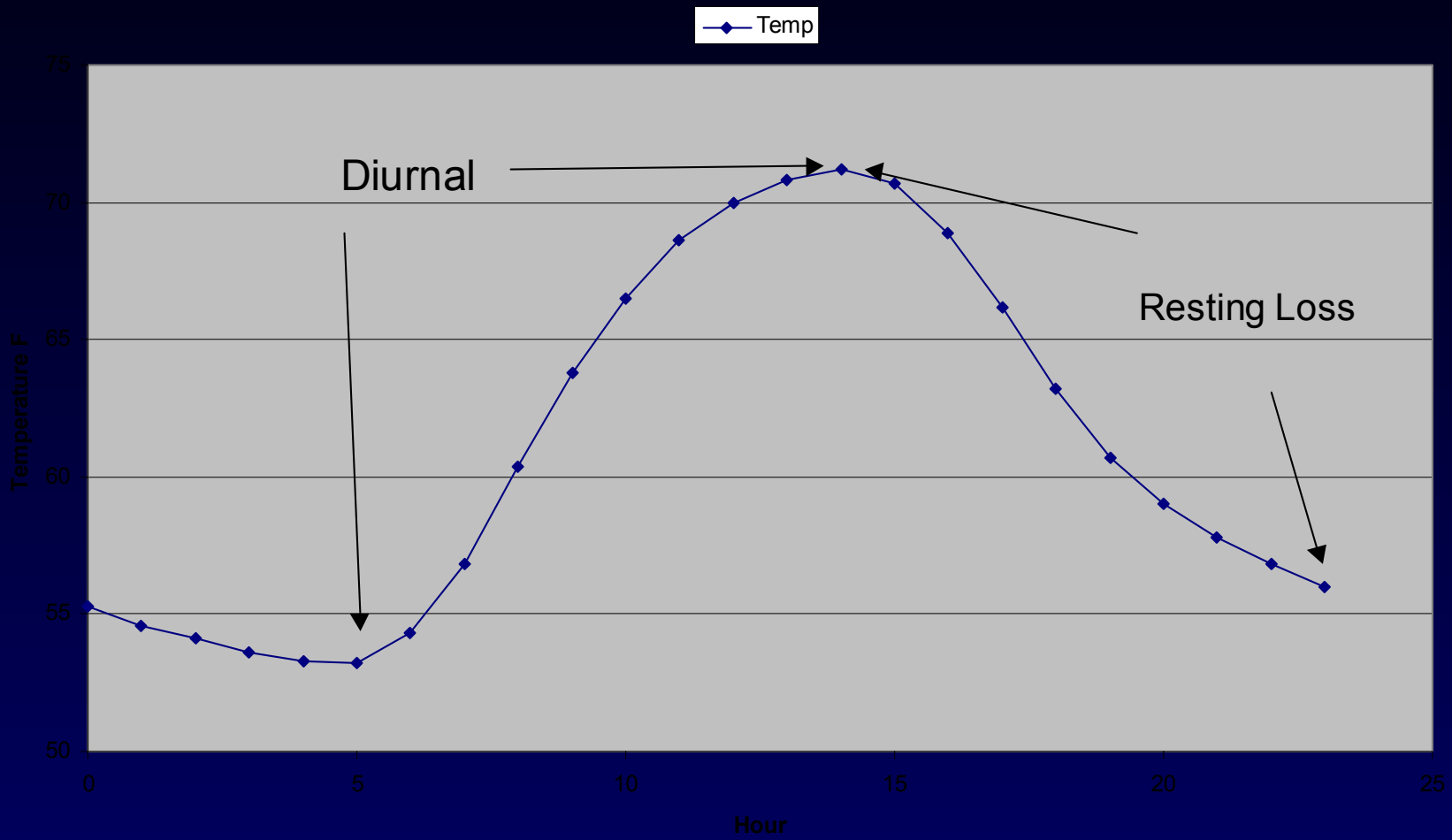
Definition

- Evaporative emission processes
  - Hot soak, diurnal, resting loss, running loss
- Hot Soak Definition
  - Evaporative emission occurs immediately after an engine event due to fuel heating after a hot engine is turned off
- Diurnal, Resting Loss Definition
  - Diurnal occurs when rising ambient temperature cause fuel evaporation from equipment sitting throughout the day

Definition (cont.)

  - Resting loss occurs when equipment is sitting but ambient temperature is falling. Caused by permeation through rubber or plastic components rather than normal daily temperature excursions
- Running Loss Definition
  - occurs when equipment is being operated
- For inventory purposes, permeation is occurring throughout all evaporative process

Evaporative Emission Temperature Profile



Data Sources

- Population ,Activity, and Growth
  - official numbers from SORE inventory approved in 1998
  - inputs were obtained from Booz-Allen Hamilton report, Power System Research (PSR) data, CSUF study (for growth) and data provided by manufacturers

Data Sources (cont.)

- lawn and garden category population and activity mainly from BAH report and manufacturers
- lawn and garden growth factor based on number of households for residential lawn and garden equipment and commercial construction for commercial lawn and garden equipment

Data Sources (cont.)

- Emission Factors
  - Limited literature data. EPA has emission factors in its NEVES report. Used only as reference.
  - Testing from ARB lab and ATL contract to estimate emission factors

Current Testing

- Current testing to obtain up to date emission factors
- Use of SHED when equipment was tested
- 24-hour diurnal tests include both diurnal and resting loss
- Episodic summertime temperature profile (65-105F), RVP 7 , Phase 2 gas used in diurnal/resting loss test - same profile used in on-road vehicle certification test

Current Testing (cont.)

- Few tests were done at different temperature/rvp profile
- Running loss test done on SORE equipment included lawnmower, trimmer, generator, and ATV

Current Testing (cont.)

	Number of Equipment Tested				
Type	Total Equipment	Summertime (65-105F)/RVP7 (Diurnal/Resting Loss)/Running Loss	Summertime (65-105F)/RVP9.5 (Diurnal/Resting Loss)	(50-90F)/RVP9.5 (Diurnal/Resting Loss)	Wintertime (48-69F)/RVP7 (Diurnal/Resting Loss)
lawnmower	18	18/4	1	1	1
trimmer/edger	8	8/1	1	1	1
leafblower	4	3/0			1
chainsaw	2	2/0			
tractor	3	3/0			1
tiller	1	1/0			
generator	5	5/1			1
ATV	4	4/2			

Current Testing (cont.)

- Baseline test procedure
  - Hot soak - 3 hour
    - Drain and refuel tank to 50% capacity
    - Operate equipment for 15 minutes at rated speed
    - Seal equipment in SHED for 3 hours at 95F
  - Diurnal
    - Cool engine and fuel to initial diurnal temperature
    - Perform one 24 hour diurnal/resting loss cycle

Current Testing (cont.)

- Running Loss
  - Each test is preceded by the same preconditioning steps used in hot soak and diurnal test
  - Tested in running loss SHED
  - Simulate in-use operation
  - Cycle repeated until fuel ran out or one hour passed
  - Lawnmower - engine and fuel tank assembly removed from chassis and installed on engine stand. “Driving cycle” approximate the weighted average time required for the ISO test (6 modes) at each load setting.

Current Testing (cont.)

- Trimmer - engine and fuel tank assembly carefully removed and mounted on engine stand. ISO cycle for trimmer specifies two operating modes - 100% load at rated speed and a low speed idle. Operate the trimmer in enclosure at full throttle and apply ISO time weighting.
- Generator - tested as an entire assembly to properly represent in-use operation with respect to fuel heating. ISO D2 cycle used.

- Repair and retest equipment with leaks
- Metal/plastic/nylon tank
  - No population data on breakdown

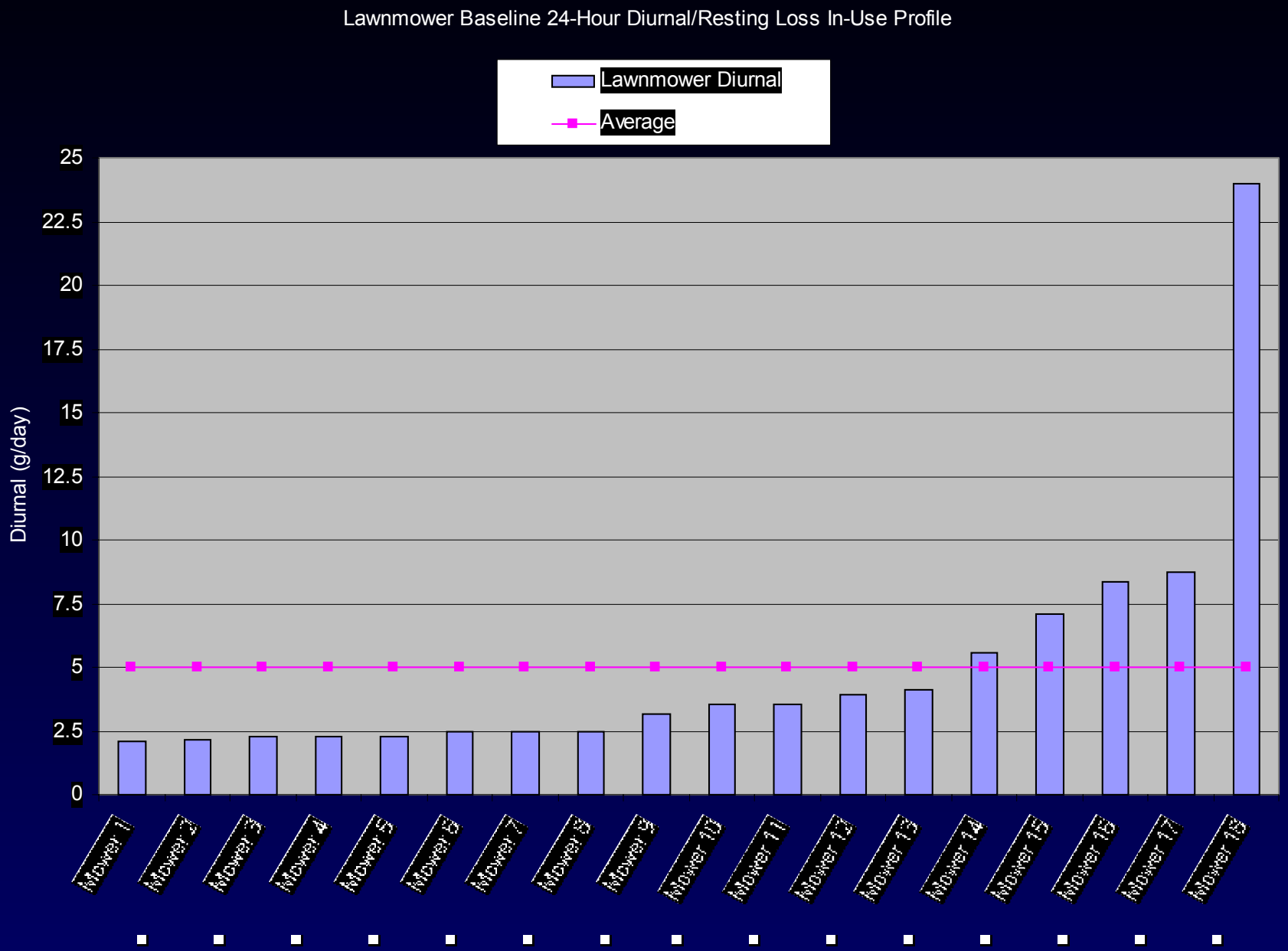
Equations

- Hot Soak
  - Event * hot soak emission factor (g/event) *rvp correction factor
- Diurnal, Resting Loss
  - Population * emission factor (g/day) * rvp/temp correction
- Running Loss
  - Population * activity * running loss emission factor (g/hr) *rvp correction factor

Estimated In-Use Baseline Emission Factors

Based on episodic temperature profile

Equipment	Hot Soak (g/event)	Diurnal/Resting Loss (g/day)	Diurnal (g/day)	Resting Loss (g/day)	Running Loss (g/hr)
Chainsaw	0.27	0.70	0.48	0.22	-
Trimmer/Edger	0.30	0.87	0.59	0.28	0.58
Leafblower	0.15	1.58	1.07	0.51	-
Lawnmower	0.95	5.03	3.22	1.81	10.29
Tiller	0.57	4.12	2.87	1.23	-
Tractor	1.52	8.70	5.57	3.13	-
Generator/Welder	4.40	10.17	9.82	0.35	4.61
ATV	3.32	14.65	11.32	3.33	12.50


Lawnmower Baseline 24-Hour Diurnal/Resting Loss In-Use Profile
Lawnmower Diurnal
Average
Diurnal (g/day)
25
22.5
20
17.5
15
12.5
10
7.5
5
2.5
0
Mower 1
Mower 2
Mower 3
Mower 4
Mower 5
Mower 6
Mower 7
Mower 8
Mower 9
Mower 10
Mower 11
Mower 12
Mower 13
Mower 14
Mower 15
Mower 16
Mower 17
Mower 18

Other Estimated Emission Factor

- Since 8 different types of equipment were tested, staff characterized the emissions of other SORE equipment types using these 8 emission factors
- Assignment based upon engine size/characteristics
- Comments are required to see if assumptions make sense

Temp/Rvp Correction Method

- Establish dataset
  - Lawnmower hour-by-hour test data from different temperature/rvp.
    - New Craftman Tecumseh lawnmower tested at epidosic temperature/rvp 7 and wintertime temperature profile/rvp7
    - New Honda Harmony II tested at epidosic temperature/rvp7, epidosic temperature/rvp9.5, and 50-90 temperature profile/rvp9.5

Temp/Rvp Correction Method (cont).

- Looked at each hour by soak hour, starting temperature, change in delta temperature and change in emissions (grams). Normalize each change in grams by full episodic summertime/rvp7 to obtain delta % change in grams.
  - For example, epidosic summertime at 65F temperature will yield 10 datapoint

Sample Dataset

Soak Hr	RVP	Temp (Starting) (F)	dTemp (F)	Actual %gram
1	7	65	1.9	0.026
2	7	65	7.6	0.064
3	7	65	15.2	0.126
4	7	65	21.3	0.214
5	7	65	25.9	0.317
6	7	65	30.1	0.434
7	7	65	33.2	0.567
8	7	65	36.7	0.708
9	7	65	38.9	0.858
10	7	65	40.5	1.000
1	7	66.9	5.7	0.037
2	7	66.9	13.3	0.099
3	7	66.9	19.4	0.188
4	7	66.9	24	0.291
5	7	66.9	28.2	0.407
6	7	66.9	31.3	0.541
7	7	66.9	34.8	0.682
8	7	66.9	37	0.831
9	7	66.9	38.6	0.974
1	7	72.6	7.6	0.062
2	7	72.6	13.7	0.151
3	7	72.6	18.3	0.254
4	7	72.6	22.5	0.370
5	7	72.6	25.6	0.503
6	7	72.6	29.1	0.645
7	7	72.6	31.3	0.794
8	7	72.6	32.9	0.936

Temp/Rvp Correction Method (cont).

- Used SAS program (general linear model (GLM)/ANOVA with interaction) to find variables that best characterize change in emissions.
  - Experiments involving a single factor or multiple factors can use analysis of variance (anova) to analyze the variation explained by those factors

Diurnal Temp/RVP Correction Factor

temperature/rvp correction factor =	(A) hr + (B) rvp + (C) temp + (D) dtemp + (E) (temp*dtemp) + (F) (temp*hr)				
	+ (G) (temp*rvp) + (H) (dtemp*hr) + I (dtemp*rvp) + intercept				
where:					
hr = number of hours					
rvp = rvp of fuel					
temp = starting temp					
dtemp = change in temp (positive number)					
	Variable	Coefficients			
	A	-0.0832099			
	B	-0.007304156			
	C	-8.10117E-05			
	D	-0.025853192			
	E	0.000175569			
	F	0.001980283			
	G	1.47497E-05			
	H	0.001471629			
	I	0.001715214			
	intercept	0.05201313			

Resting Loss Temp/RVP Correction Factor

temperature/rvp correction factor =	(A) hr + (B) rvp + (C) temp + (D) dtemp + (E) (temp*dtemp) + (F) (temp*hr)				
	+ (G) (temp*rvp) + (H) (dtemp*hr) + I (dtemp*rvp) + intercept				
w here:					
hr = number of hours					
rvp = rvp of fuel					
temp = starting temp					
dtemp = change in temp (negative number)					
	Variable	Coefficients			
	A	0.032988944			
	B	0.041684179			
	C	0.005296275			
	D	0.06209003			
	E	-0.000459595			
	F	0.000596396			
	G	-0.000500966			
	H	0.000804361			
	I	-0.002281295			
	intercept	-0.40806693			

Temperature Profiles - Statewide

EMFAC Temperature Profile					
	Summer	Winter		65-105	
Hour	Temp	Temp		Temp	
0	62.6	51.5		65	
1	61.9	50.4		66.6	
2	61.1	49.7		72.6	
3	60.6	49.1		80.3	
4	60	48.9		86.1	
5	59.6	48.5		90.6	
6	60.4	48.4		94.6	
7	63.9	49.2		98.1	
8	68.7	52.6		101.2	
9	73.1	57.7		103.4	
10	76.6	62.2		104.9	
11	79.4	65.6		105	
12	81.4	67.8		104.2	
13	82.8	68.8		101.1	
14	83.5	69.2		95.3	
15	83.3	68.8		88.8	
16	81.9	66.9		84.4	
17	79.3	63.4		80.8	
18	75.5	59.7		77.8	
19	71.5	57.3		75.3	
20	68.5	55.7		72	
21	66.6	54.4		70	
22	65.1	53.4		68.2	

Effect of Temperature/RVP Correction

Evaporative Process	Annual Average	Summer Average	Winter Average
Diurnal	.406	.550	.206
Resting Loss	.929	.923	.938

Estimated 2000 State Baseline Inventory (SORE)

Annual Average							
HH/NHH	P/N	2000 Pop	2000 Hot soak (tons/day)	2000 Diurnal (tons/day)	2000 Resting Loss (tons/day)	2000 Running Loss (tons/day)	2000 Total (tons/day)
HH	N	1609247	0.34	0.49	0.53	0.18	1.55
	P	207336	0.04	0.04	0.05	0.06	0.19
HH Total		1816583	0.38	0.54	0.58	0.24	1.74
NHH	N	3533295	4.31	5.73	5.71	4.77	20.52
	P	268042	1.00	0.91	0.40	1.12	3.43
NHH Total		3801337	5.31	6.65	6.11	5.89	23.95
Grand Total		5617920	5.69	7.18	6.69	6.13	25.70

Equipment	2000 Pop	2000 Hot soak (tons/day)	2000 Diurnal (tons/day)	2000 Resting Loss (tons/day)	2000 Running Loss (tons/day)	2000 Total (tons/day)
Lawnmower	2513937	1.78	3.62	4.66	2.91	12.97

Estimated 2020 State Baseline Inventory (SORE)

Annual Average							
HH/NHH	P/N	2020 Pop	2020 Hot soak (tons/day)	2020 Diurnal (tons/day)	2020 Resting Loss (tons/day)	2020 Running Loss (tons/day)	2020 Total (tons/day)
HH	N	2089109	0.44	0.64	0.69	0.24	2.01
	P	267793	0.06	0.06	0.06	0.07	0.24
HH Total		2356902	0.50	0.70	0.75	0.30	2.25
NHH	N	4526835	5.29	7.24	7.38	6.08	25.99
	P	320139	1.16	1.06	0.47	1.30	3.99
NHH Total		4846973	6.45	8.31	7.85	7.38	29.99
Grand Total		7203876	6.95	9.01	8.60	7.68	32.24
Equipment		2020 Pop	2020 Hot soak (tons/day)	2020 Diurnal (tons/day)	2020 Resting Loss (tons/day)	2020 Running Loss (tons/day)	2020 Total (tons/day)
Lawnmower		3263808	2.31	4.70	6.05	3.78	16.83

Future Development

- Examine deterioration factor/liquid leakers
- Incorporate partial diurnal/partial resting losses